

Performing a Basic US Examination: A Road Map for Radiology Residents

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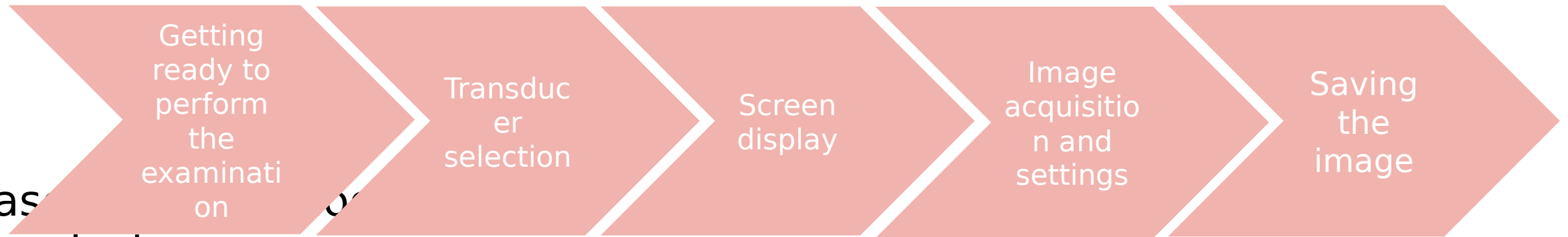
Certificate of Merit Award Recipient

Acknowledgments: We would like to thank our sonographers who do this every day and make it look easy. Thank you for all your hard work and for being wonderful teachers.

Disclosures of Conflicts of Interest.—B.F.L. *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* royalties from Elsevier. *Other activities:* disclosed no relevant relationships. **J.J.W.** *Activities related to the present article:* disclosed no relevant relationships. *Activities not related to the present article:* royalties from Elsevier. *Other activities:* disclosed no relevant relationships.

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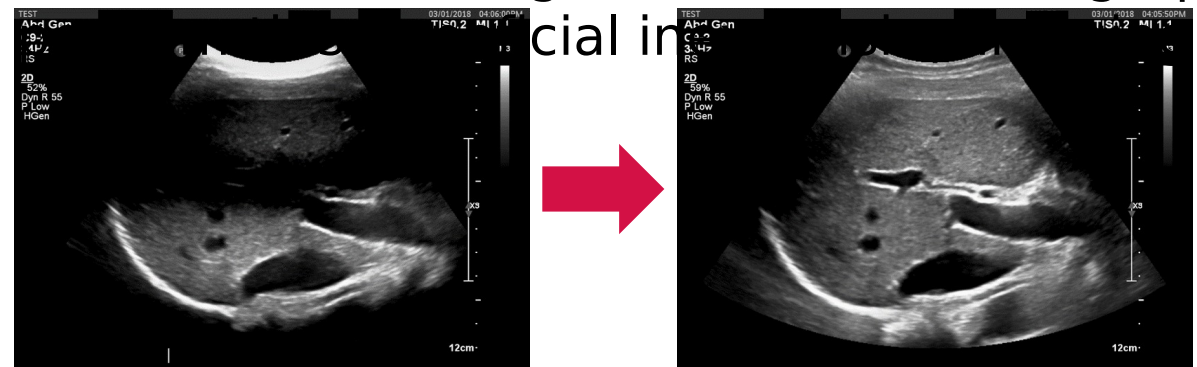


- Case
- Conclusion

Note: Most of the images in this presentation were obtained using an EPIQ 7 US machine (Philips Healthcare, Best, the Netherlands). This information is for learning purposes only. This is not an endorsement of any specific manufacturer. Other manufacturers will have varied machine and screen displays. For specific instructions for specific controls or displays, the best first step is to refer to the user manual for each specific type of equipment.

Background

- Performing a quality US examination is operator and patient dependent. Obtaining optimal images requires practice. Despite the increase in US use by practitioners in other medical specialties,¹⁻³ radiology trainees in the United States are spending less time learning the nuts and bolts of performing US scanning.⁴⁻⁷
 - Benefits of obtaining competency in US scanning include:
 - ✓ Improved image interpretation and patient management
 - ✓ Ability to recognize suboptimal images, troubleshoot problems, and overcome operator dependency
 - ✓ Increased technical and interpretive added-value for referring clinicians and sonographers
 - ✓ Radiologist empowerment to continue to expand their role in this modality
- This presentation reviews the steps one should take to produce an excellent gray-scale US image. Tips for improving image quality and decreasing artifacts will also be presented.

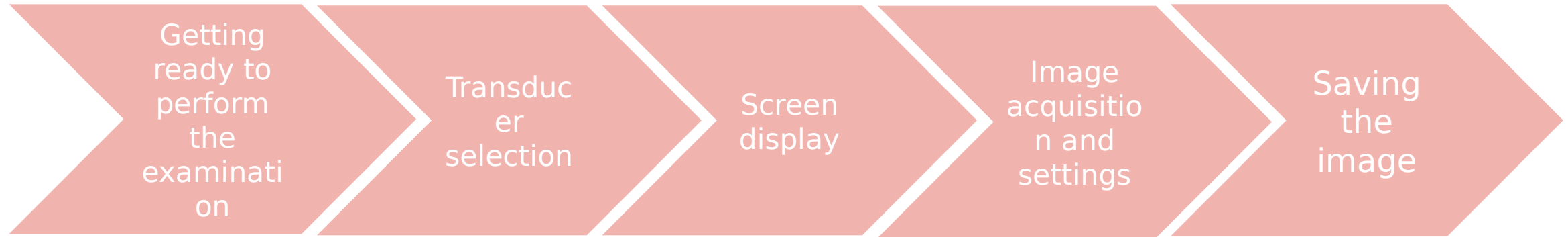


Learning Objectives

At the end of this presentation, you should be able to:

- ☐ Execute the basic steps to obtain a high-quality gray-scale US image.
- ☐ Understand the fundamental physics and concepts that affect US image acquisition and optimization.
- ☐ Recognize and correct suboptimal US gray-scale images.

The Road Map



Ask yourself...

What equipment and/or materials do I need?

- US machine and transducer
- Gel
- Other materials?
 - Gel warmer, standoffs, and transducer cover

How should I position the patient?⁸

- Supine is not the only option! Other positions include right or left lateral decubitus, semi-erect, or prone.
- US is a dynamic evaluation

What is the examination protocol?

- Patient instructions can be crucial
 - Breath holding, Valsalva maneuver
- Varies by institution
- Affects the acquisition of specific images and the use of labels

How should I position myself and the equipment?⁸⁻¹⁰

- Ergonomic practices minimize repetitive stress injuries—make sure you are comfortable!
- Adjust the examination table, chair height, and the patient's position.
- Keep the scanning arm close to your side and supported.
- Maintain a neutral wrist.
- Place the screen in front at eye-level and the control panel within reach of the nonscanning arm



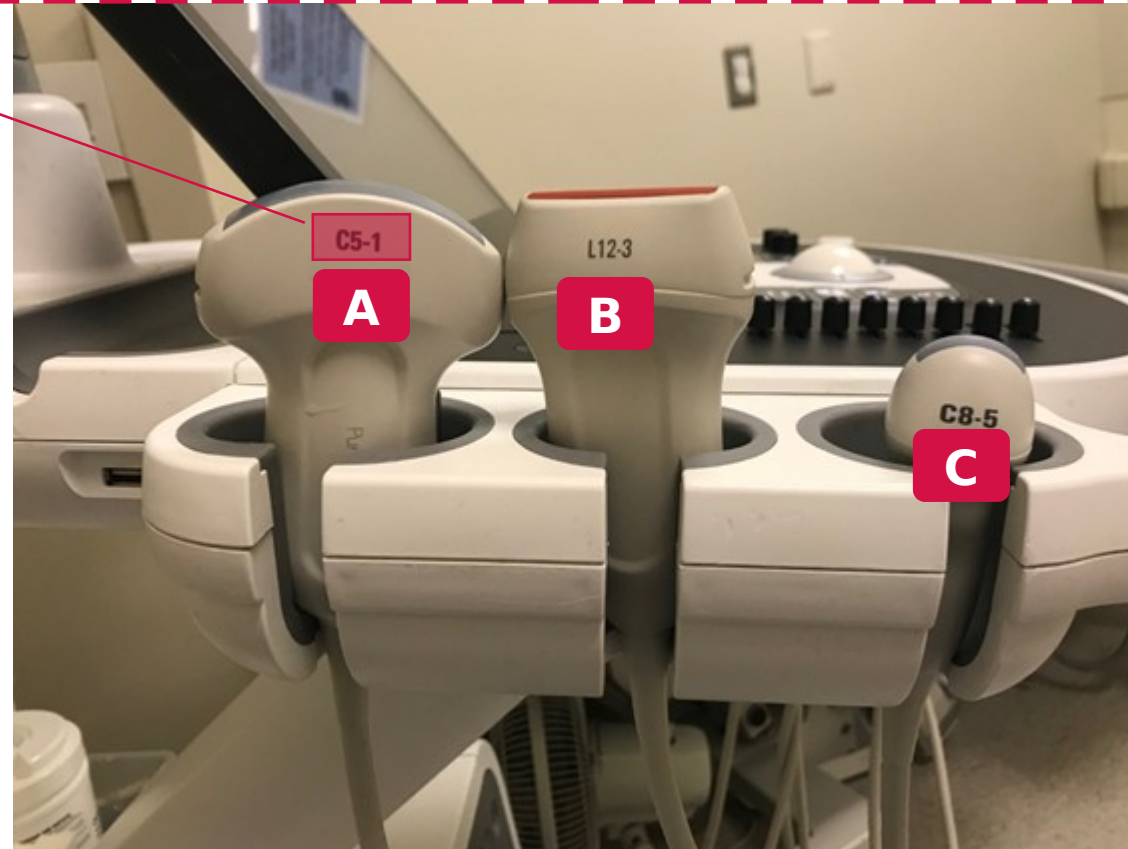
Key Points:

- Transducers vary in **shape, size, and frequency**.
- Consider the access needed to visualize the region of interest (acoustic window, footprint, and transducer shape) and the extent of the imaging target (depth, frequency, width, and FOV).¹¹
- Select the highest-frequency transducer that can penetrate to the needed depth to image the area of interest.¹²

The label indicates the type of transducer and its frequency range or

A. Curvilinear transducer

- ✓ Low-frequency (5-1 MHz)
- ✓ Wide convex footprint
- ✓ Ideal for examinations requiring depth and a wide field of view (FOV) (eg, abdominal or obstetrical examinations)



B. Linear transducer

- ✓ High-frequency (12-3 MHz)
- ✓ Medium footprint
- ✓ Ideal for superficial structures (eg, vascular structures, thyroid, scrotum, and extremities)

C. Sector or phased array transducer

- ✓ Mid-range frequency (8-5 MHz)
- ✓ Small footprint
- ✓ Ideal for small acoustic windows (eg, intercostal spaces, cardiac applications, and the neonatal brain)

Key Point: Understanding the screen display and image notations improves image interpretation, especially when evaluating images acquired by a colleague.

Image shows the screen display for an abdominal US examination. Click to see the explanations of the colored labels.

Demographic information

(red rectangle)

- Patient name
- Medical record number
- Examination date and time

Imaging Parameters

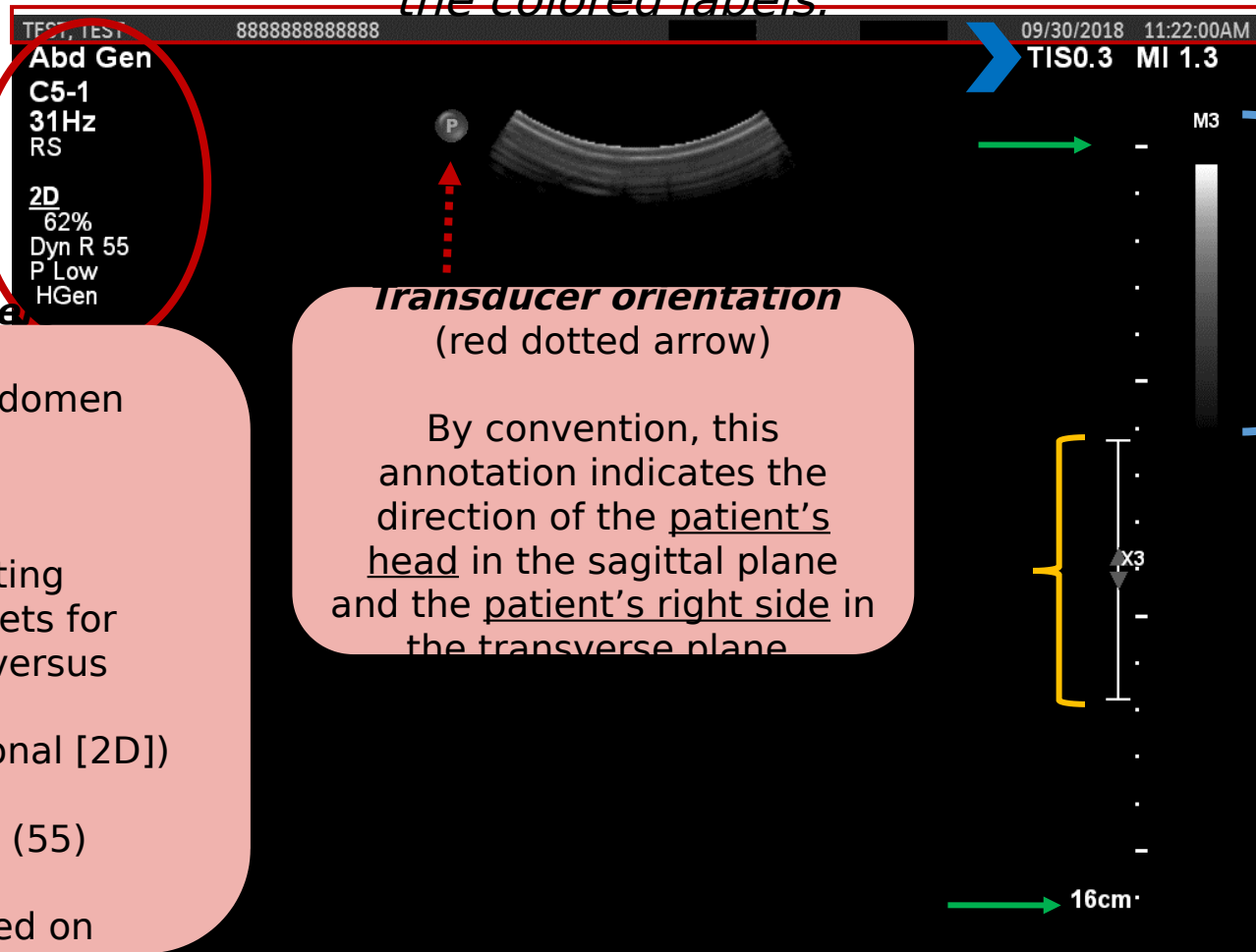
(red circle)

- Examination preset: abdomen general (Abd Gen)
- Transducer type (C5-1)
- Frame rate (31 Hz)
- Dynamic resolution setting (RS is one of the presets for optimizing temporal versus spatial resolution)
- US mode (two dimensional [2D])
- Gain (62%)
- Dynamic range (Dyn R) (55)
- Power output (P) (low)
- Harmonics setting turned on (HGen)

Transducer orientation

(red dotted arrow)

By convention, this annotation indicates the direction of the patient's head in the sagittal plane and the patient's right side in the transverse plane



Key Point: Understanding the screen display and image notations improves image interpretation, especially when evaluating images acquired by a colleague.

Blue arrowhead points to:

Image shows the

Thermal Index (TI)

- ✓ Measure of an US beam's thermal bioeffects (eg, heating risk)
- ✓ TI greater than 1.0 represents relative increased risk of heating
- ✓ U.S. Food and Drug Administration (FDA) limit = 1.0 for ophthalmic applications, 6.0 for others

Mechanical Index (MI)

- ✓ Estimates the risk of cavitation-related bioeffects
- ✓ FDA limit = 1.9

FDA safety regulation requires the display of

Focal Zone

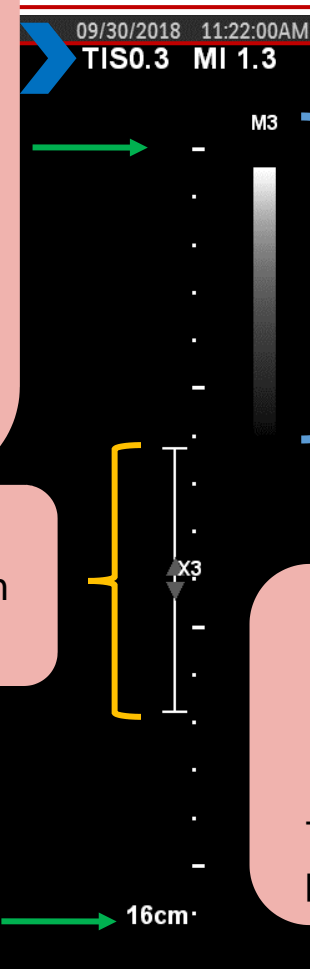
Set to 6-12 cm depth.

Gray-scale Map

Depth

Each dot represents 1 cm.

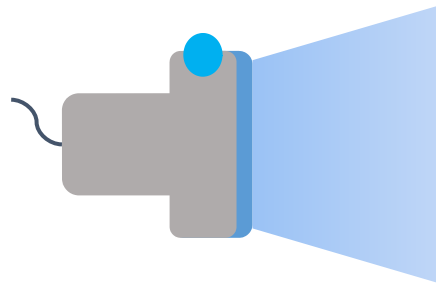
The green arrows point to 0 cm and 16 cm depth.



Transducer Orientation



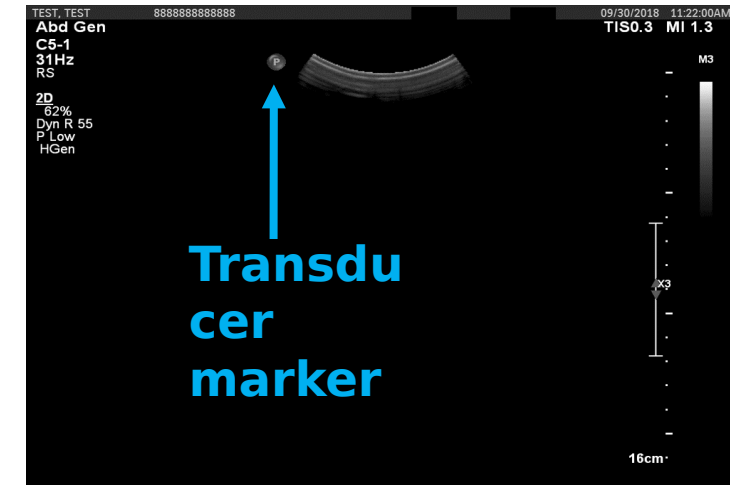
Transducer
marker



Orient the transducer in the **cephalad** position to obtain **coronal** and **sagittal** views.

Orient the transducer to the **patient's right side** to obtain **transverse** views. If the long axis of the organ to be imaged is not parallel to the long axis of the body, then:

1. Align the transducer along the long axis of the organ with the marker cephalad; and
2. Rotate the transducer 90 degrees so that the marker is pointing to patient's right side.

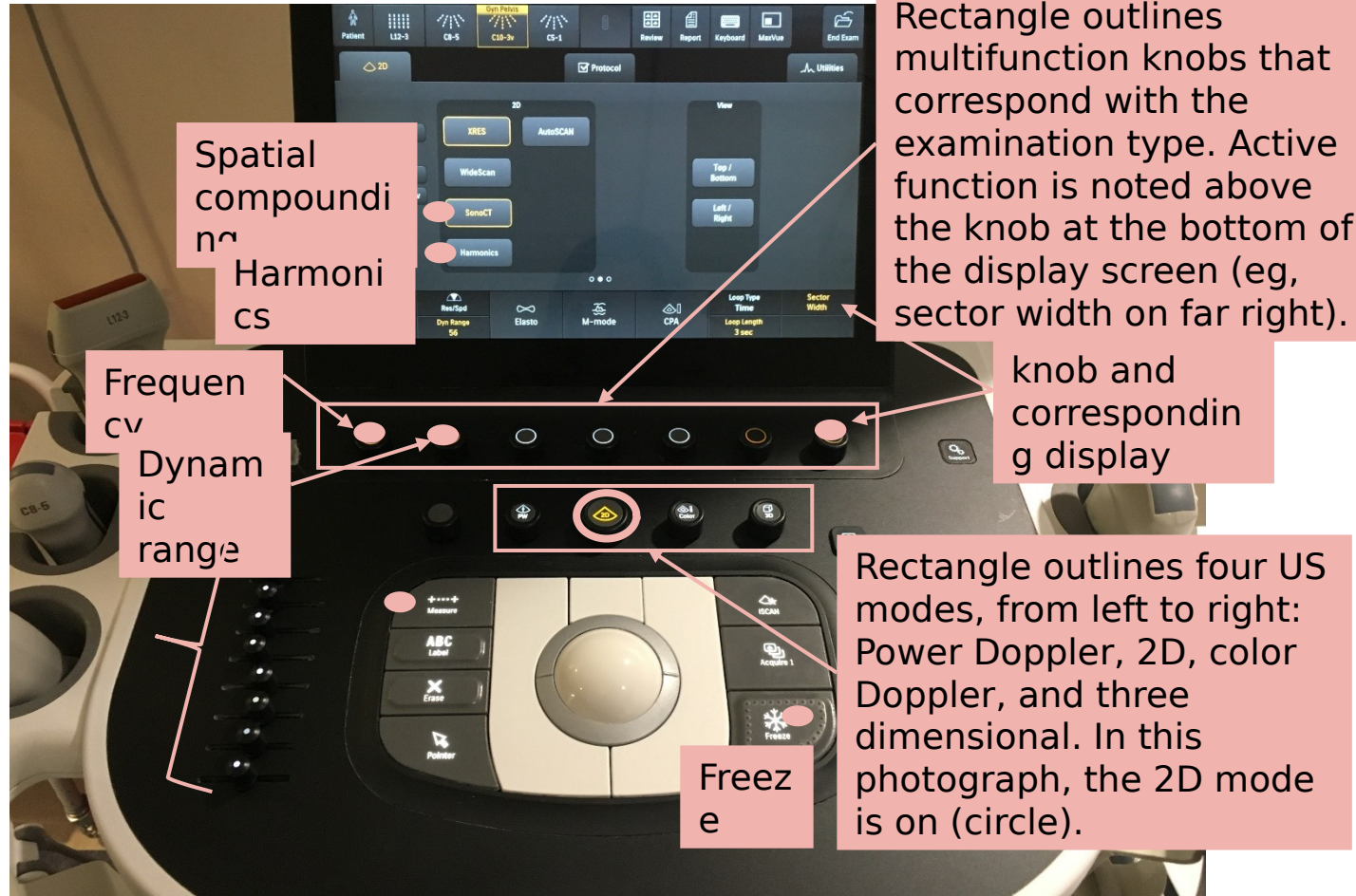


Key Points:

- Transducers have a marker for image orientation.
- Orient the transducer marker toward the patient's right side to obtain transverse images.
- Orient the transducer marker cephalad (toward the patient's head) to obtain sagittal and coronal images.

The Console (“Knobology”)

This next section reviews each of the major controls on the US machine console. The photograph shows a general landscape of a console in 2D mode. **Click to see label buttons.**

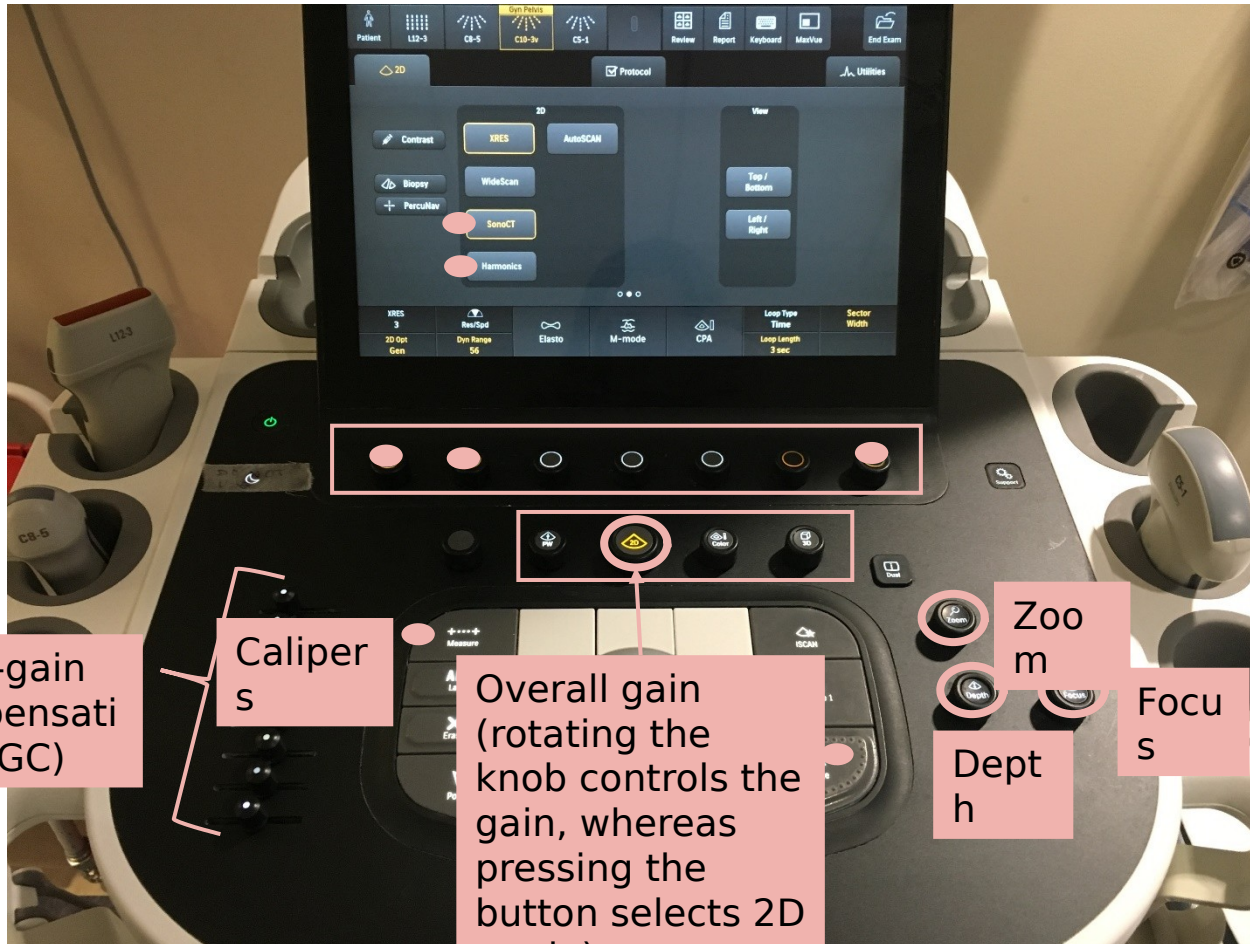


Tip: There are an overwhelming number of settings on a US console. When starting out, it is useful to understand the following controls:

- Gain
- Frequency
- Focus
- Gray scale/dynamic range
- Depth and sector width

The Console (“Knobology”)

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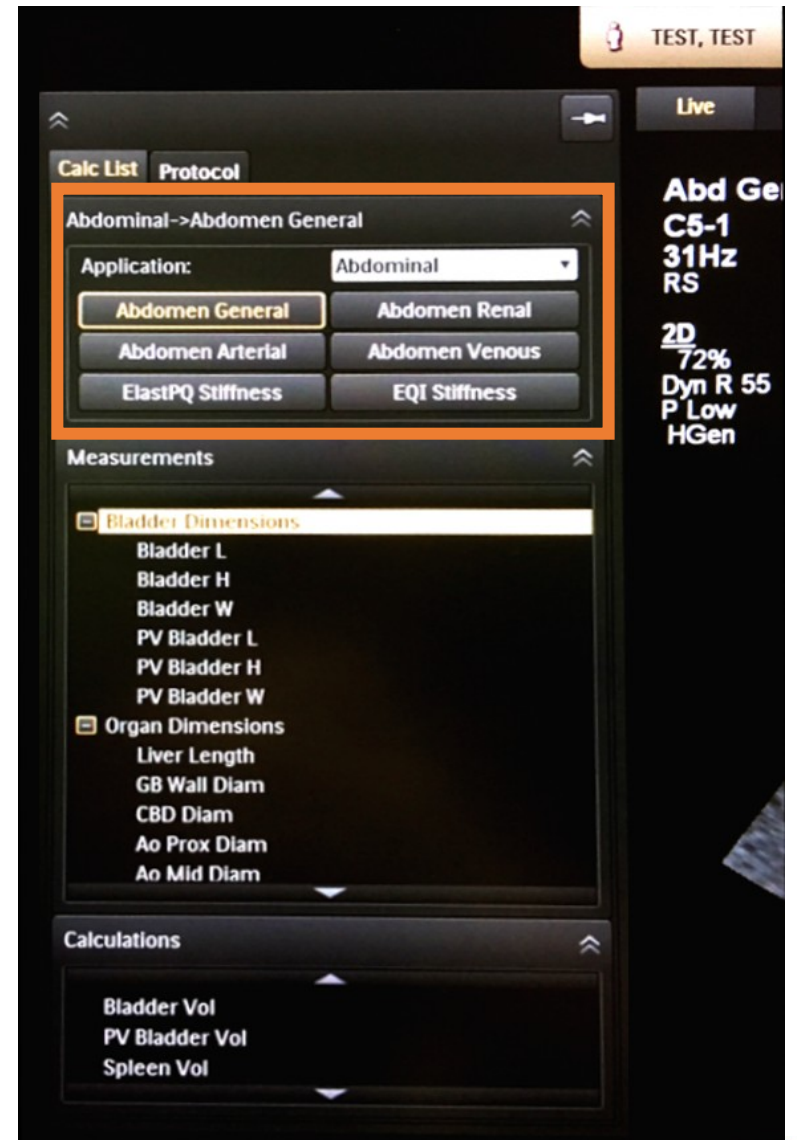
Examination Presets^{8,14}

- Menu of common examination types (rectangle)
 - Abdomen general, obstetric, etc
 - “Abdomen General” is selected in the accompanying screen shot.
- Contains preestablished parameters and common measurements for the selected examination type
- Vendor specific
- Transducer dependent

Can sometimes be customized

Key Points:

- Always reset the examination presets before beginning each study.
 - Adjust the presets accordingly for each specific study.
- Know the institutional protocol.

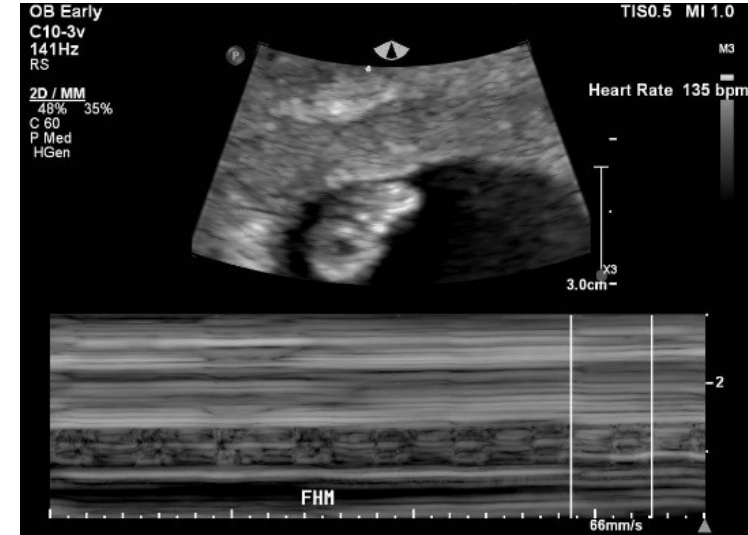


Display Modes¹²



Gray-scale US (2D, B-mode)

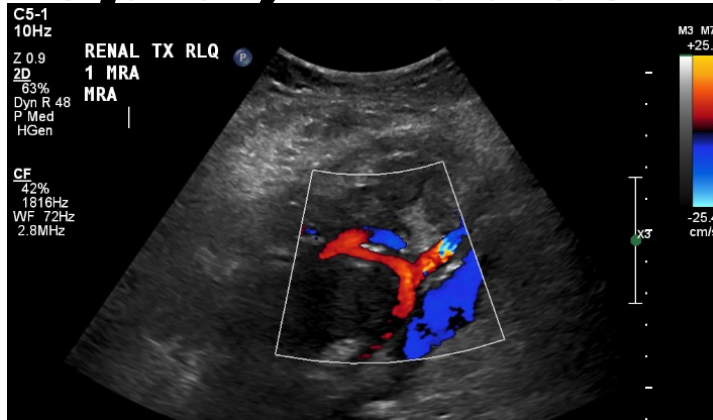
- Mainstay of US
- Pulse-echo approach → transducer emits energy pulses that are reflected back by acoustic interfaces within the body
- Reflective structures are hyperechoic on the image (**think: B = Brightness mode**)
- Signals with the greatest intensity appear white, absent signals appear black, and those in between appear as shades of gray.



M-mode (motion mode)

- Displays changes of echo amplitude and position over time
- Useful for evaluating rapidly moving structures (eg, cardiac valves, fetal heart rate)
- Used in cardiac imaging to detect cardiac motion and the movement of various parts of the heart (**think: M = mitral valve mode**)

Display Modes¹²

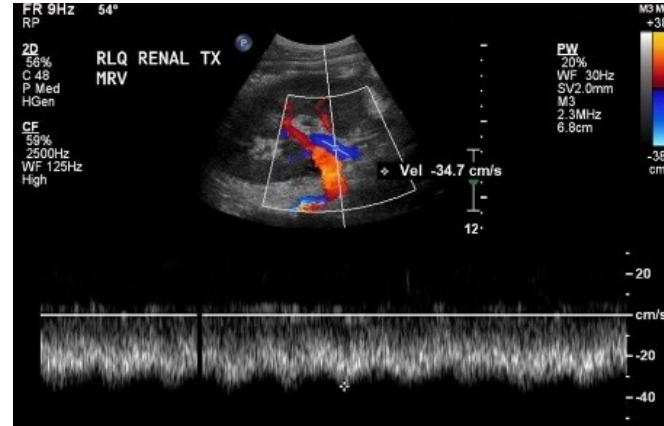


Color Doppler

- Color is superimposed on B-mode US images
- Color scale on the side of the image indicates the flow direction
- **Red** = flow **toward** the transducer

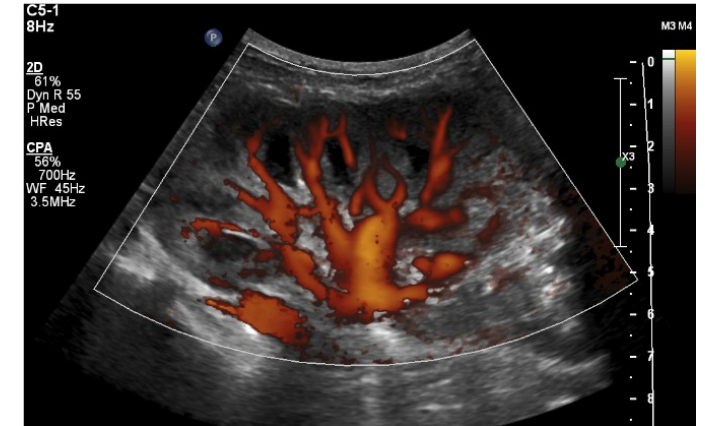
• **Blue** = flow **away** from the transducer

Key Points: Frequently used image-display types include real-time gray-scale (B-mode), M-mode (motion mode), and Doppler US. While B- and M-modes display information regarding tissue interfaces, Doppler US interprets blood flow and can be further specified as color, spectral, or power.



Spectral Doppler

- Displayed as a pulse wave
- Displays the blood vessel waveform and calculates the flow velocity
- Flow toward the transducer = above baseline
- Flow away from the transducer = below baseline



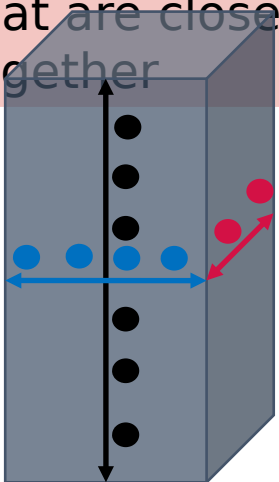
Power Doppler

- Flow sensitive
- Uses a color map to show amplitude but not the flow direction or velocity
- Useful to detect blood flow in low-flow organs

Basic review of some important physics

Resolution = ability to identify two closely apposed objects as separate entities¹⁵

Spatial resolution = ability to discriminate two separate objects that are close together



Temporal resolution = ability to accurately locate structures at a specific point in time

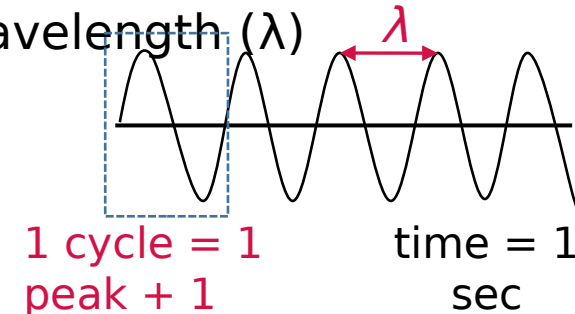
Axial resolution = Parallel to the ultrasound beam; affected by **the spatial pulse length (SPL)**

Lateral resolution = Along the image plane (perpendicular to the axial plane); affected by **beam width and focal zone**

Elevational resolution = In the direction of section thickness (perpendicular to imaging plane); inherent to the transducer; **not adjustable**

- Frequency (f)** = Number (#) of cycles per second (sec) that a wave undergoes, measured in units of hertz (Hz); inversely related to wavelength (λ)

$$f =$$



- SPL** = # cycles in an emitted ultrasound pulse $\times \lambda$; affects axial resolution¹⁶
- Penetration** = Minimum depth at which electronic noise is visible despite setting optimized controls¹¹

Key Point:



transducer
r f

↓ λ , ↓ SPL, ↑ **axial resolution**

↓ beam width, ↑ **lateral resolution**

↓ λ , ↑ attenuation, ↓ **penetration**

Note.— ↓ = decrease, ↑ = increase

Optimizing Frequency

US images (a,b) show the liver surface.

(a) US image obtained using a low-frequency transducer (C 5-1) shows better penetration than that of **b**, which allows for the evaluation of the liver parenchyma. However, resolution is limited.



(b) US image obtained with a higher-frequency transducer (L 12-5) shows better resolution than that of **a**. In this case, the micronodularity of the liver surface is better depicted. Note that the trade-off for improving resolution is poorer penetration.

Key Points:

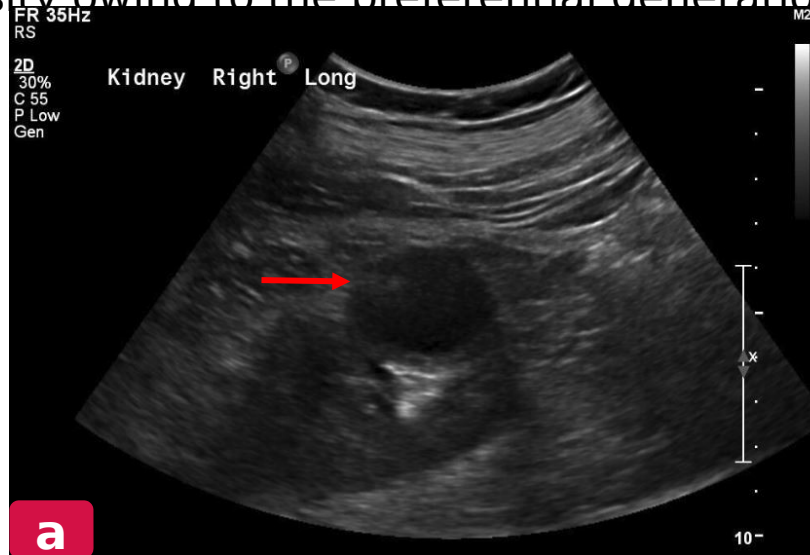
- Increasing the frequency improves resolution but at the expense of penetration. Accordingly, using a transducer with a higher frequency is best for imaging superficial targets, whereas a lower-frequency transducer best depicts deeper targets or works best for imaging patients with obesity.
- In general, use the highest frequency possible for a particular application.
- Adjust the frequency by selecting a different transducer or changing the frequency range for a particular transducer.

Frequency and Tissue Harmonic Imaging

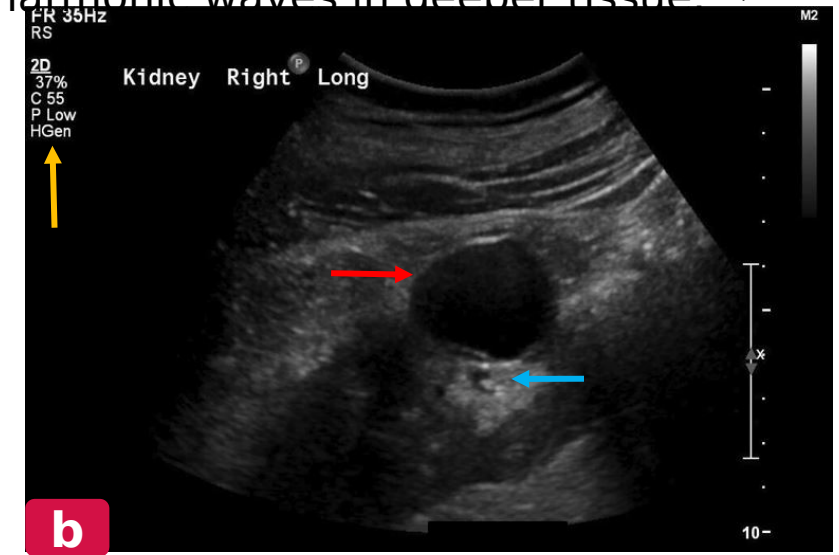
(THI)
An ultrasound wave propagating through tissue creates harmonics (multiples of the transmitted frequency). THI creates an image from the second harmonic ($2f$). THI reduces speckle (ie, noise), especially in the near field; decreases many artifacts and can enhance others; and improves signal-to-noise ratio, lateral resolution, and image quality in patients with obesity owing to the preferential generation of harmonic waves in deeper tissue.^{16,17}

Effects of THI on various artifacts:

- ↓ Reverberation artifact
- ↓ Side lobe artifact
- ↓ Grating lobe artifact
- ↑ Acoustic enhancement
- ↑ Acoustic shadowing
- ↑ Comet-tail artifact



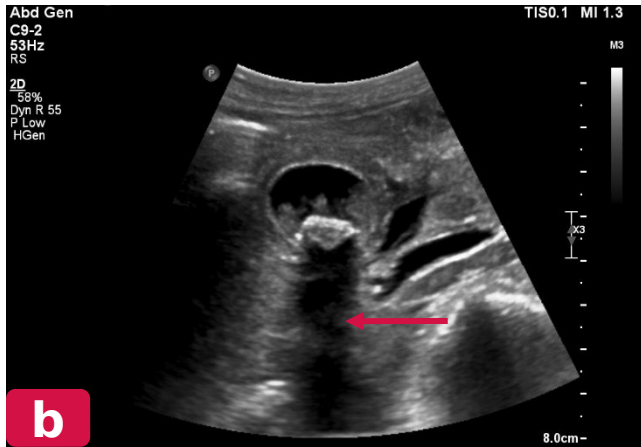
(a) US image shows a renal cyst and indicates that the THI setting is **OFF** in the display. Note the side lobe artifact (red arrow) within the cyst.



(b) US image shows a renal cyst and indicates that the THI setting is **ON** (yellow arrow) in the display. Note the reduced side lobe artifact (red arrow) within the cyst and better cyst clearing. The back wall and posterior acoustic enhancement (blue arrow) are better depicted.

Key Point: THI improves resolution, decreases noise, and reduces some artifacts. It is particularly useful for imaging cystic structures, abnormalities that contain fat, calcium, or air, and patients with obesity.¹⁷

THI Examples



Effect of THI on shadowing:

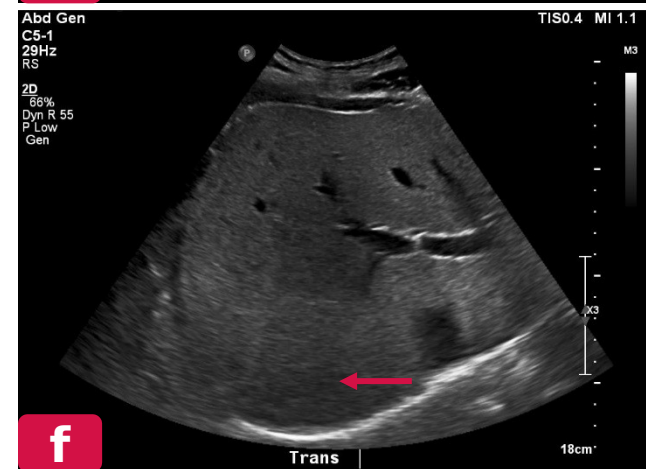
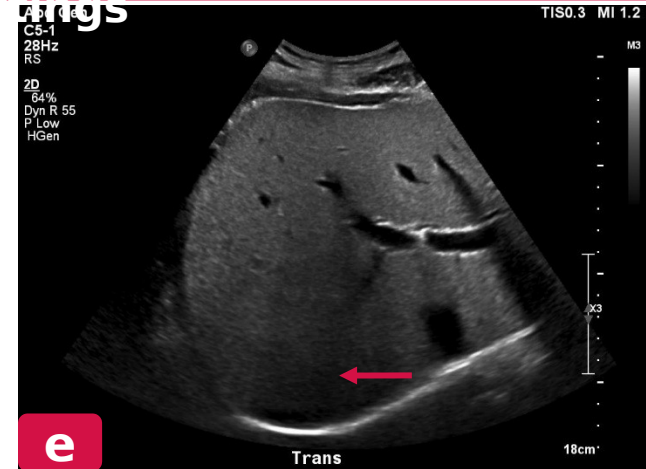
(a) US image shows a gallstone. THI is **OFF**

(b) US image shows a gallstone. THI is **ON**. Note the increased shadowing (arrow).

Effect of THI on comet-tail artifact:

(c) US image shows a thyroid nodule. THI is **OFF**

(d) US image shows a thyroid nodule. THI is **ON**. Note the improved characterization of echogenic foci as colloid foci owing to improved



Effect of THI on posterior attenuation in a fatty liver:

(e) US image shows a fatty liver. THI is **ON**. Note the attenuation of the ultrasound beam (arrow) by the fat at increased depths.

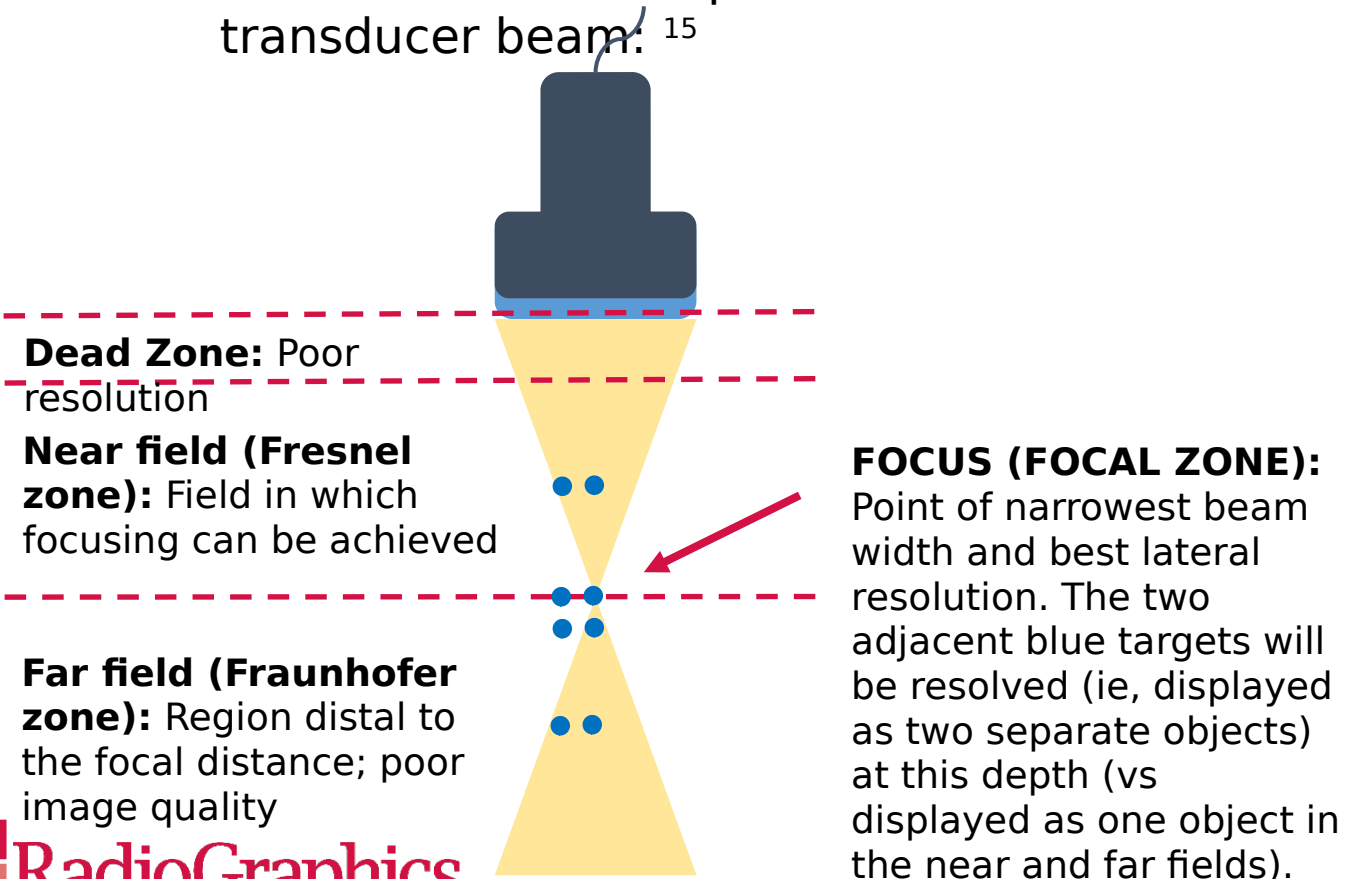
(f) US image shows a fatty liver. THI is **OFF**.

Because of the increased attenuation of the higher second harmonic frequency owing to fat, turning THI

Focus

The focus setting narrows the transducer beam width at a determined focal point in order to **optimize lateral resolution**.¹⁸ The focus should be set at or just deep to the target of interest.

To understand how focusing works, let's review the components of a transducer beam.¹⁵

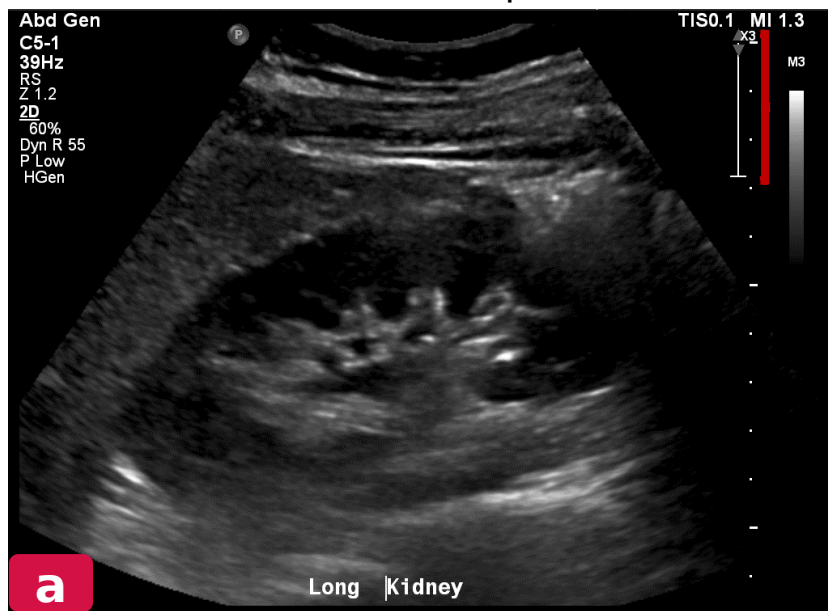


Some words of caution:

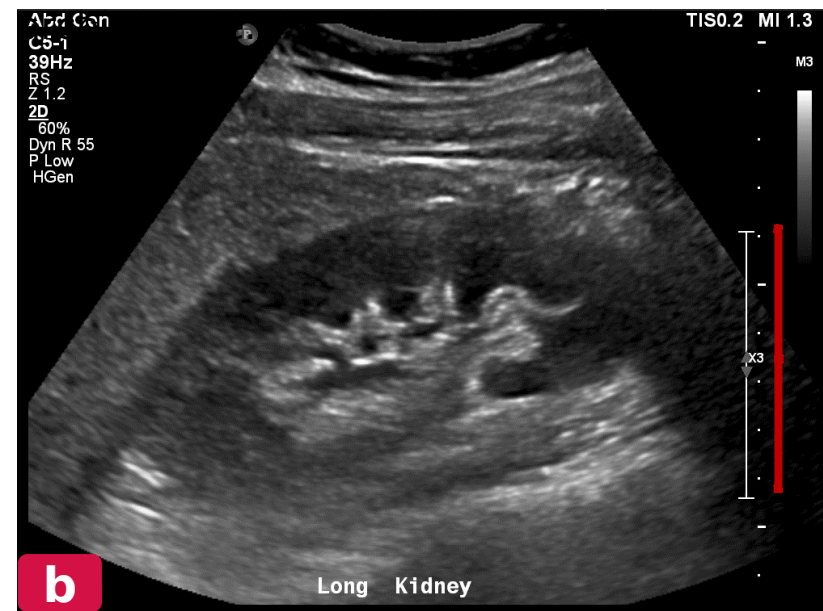
- Inappropriate focal zone placement can decrease shadowing artifact, which is required to diagnose certain conditions (eg, stones).¹⁸
 - If the beam width is greater than the stone diameter, shadowing may not be visible. Place the focal zone at the stone to maximize shadowing.
- Multiple focal zones (multifocus) can be selected. However, this may slow down the image frame rate (ie, decrease the temporal resolution).⁸

Optimizing Focus

(a) US image shows the right kidney with an inappropriately placed focal zone at 0–3 cm (**bracket**). Note that the renal architecture is not well depicted.



(b) US image of right kidney obtained with focal zone set at 4–9 cm (**bracket**). Note the improved resolution, which enables better visualization of the renal



(c) Photograph of the US machine console shows the focus knob (**circle**). Turning the knob clockwise decreases the depth of the focal



Key Points:

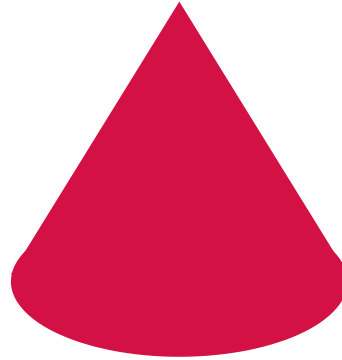
- Optimizing focus improves beam width and lateral resolution. The focal zone should be set at or just deep to the target.
- Inappropriate focal zone placement may decrease shadowing artifact needed for diagnosis (eg, in cases of imaging stones).

FOV: Shape, Depth, and Sector Width

The shape of the display is dependent on the transducer type being used and its function. Common shapes include:¹¹



2D
Rectangular



2D Sector



2D Convex or
Curved



2D Trapezoidal



Photograph of a US machine console shows the **sector width** (pink circle) and **depth** (red circle) knobs.

FOV: Shape, Depth, and Sector Width



(a) Transverse US image of the liver obtained with a depth inappropriately set to 22 cm.

(b) Transverse US image of the liver obtained with a depth optimized at 12 cm.

(c) Transverse US image of the pancreas obtained with a narrow sector width.

(d) Transverse US image of the pancreas obtained with an optimized sector width.

Key Point: FOV shape is transducer dependent. Depth and sector width allow for adjustments to the FOV. They should be set at the minimum required levels to visualize the structures of interest while using the entire screen. The trade-off for increased depth and width is a reduced frame rate (temporal resolution).

Gain^{8,12,18}

- As sound waves travel through tissue, their amplitude reduces with increasing distance owing to tissue absorption, acoustic reflection, scattering, and beam divergence. This phenomenon is known as ***attenuation***. The amount of attenuation varies greatly depending on the type of tissue being imaged.
- Echoes returning from deeper tissues will be weaker than those produced from more superficial tissues, which can result in a heterogeneous US image.
- Gain describes the mechanism that enables the transducer receiver to amplify signal. ***Gain can profoundly impact the quality of an image for interpretation.***
- The operator can manipulate gain by adjusting the following four settings:
 1. **Auto-optimize:** Most US machines have an auto-optimization setting.
 2. **Overall gain:** Amplifies all signals by a constant factor regardless of depth; ↑ **overall image brightness**
 3. **TGC or depth gain compensation:** Can amplify or suppress signals dependent on the tissue depth;
↑ **homogeneity of the image over all depths**
 4. **Lateral gain compensation:** Adjusts image brightness at selective widths.

Optimizing Overall Gain

Overall gain setting amplifies all signals by a constant factor, regardless of depth. Use this technique if the whole US image



(a) US image of the liver obtained with an overall gain that was set too high (75%, **arrow**). Note the brightness of the image.

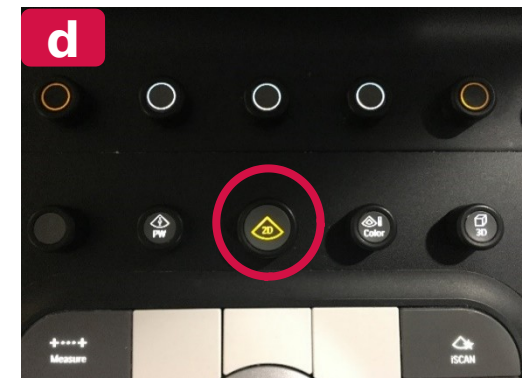


(b) US image of the liver obtained with an overall gain that was set too low (52%, **arrow**). Note the darkness of the image.



(c) US image of the liver obtained with overall gain optimized (66%, **arrow**). Note the improved visualization.

Key Points: The overall gain affects the image brightness. As gain electronically amplifies the signal of the returning echo, it does not affect the initial pulse strength. Therefore, it does not affect the energy deposition in the patient. When increased image brightness is desired, the gain should be the first thing adjusted (before Power output).



(d) Photograph of the US machine console shows the knob used to adjust the overall gain (**circle**). Rotating the knob clockwise increases the

Optimizing TGC

Slide pods on the US machine console adjust image brightness at selective depths. Adjust this setting if the image needs correction at a certain depth and to improve image homogeneity by depth.



(a) US image of the liver obtained while the TGC was not optimized at the deeper levels. Note the darkness at 10–14 cm (**bracket**).



(b) US image of the liver obtained with an overcorrected TGC at the deeper levels. Note the brightness at 10–14 cm (**bracket**).



(c) US image of the liver obtained with TGC optimized. Note the uniform brightness of the image displayed at all depths.



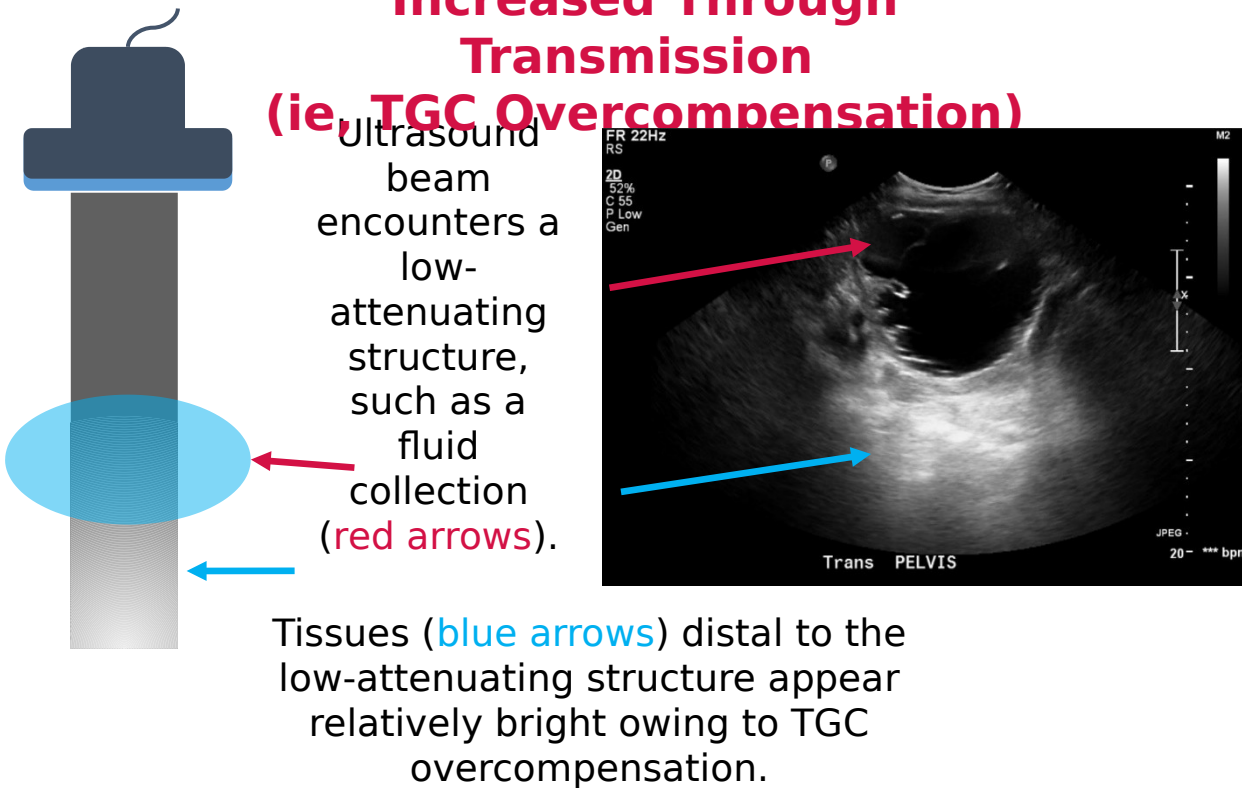
(d) Photograph shows the TGC slide pods (**rectangle**) on the console. Each pod corresponds to a particular depth. Sliding right increases gain; sliding left decreases gain. Remember the rhyme, “Right bright, left lessens.”

- Key Points: Echoes returning from deeper structures have weaker amplitude owing to tissue attenuation. This results in a heterogeneous image, with the deeper structures appearing dark. This can be corrected with TGC.
- TGC amplifies signals from deeper tissues or suppresses signals from superficial tissues to overcome the effects of attenuation. As a result, equally reflective structures display equal brightness, regardless of depth.¹²

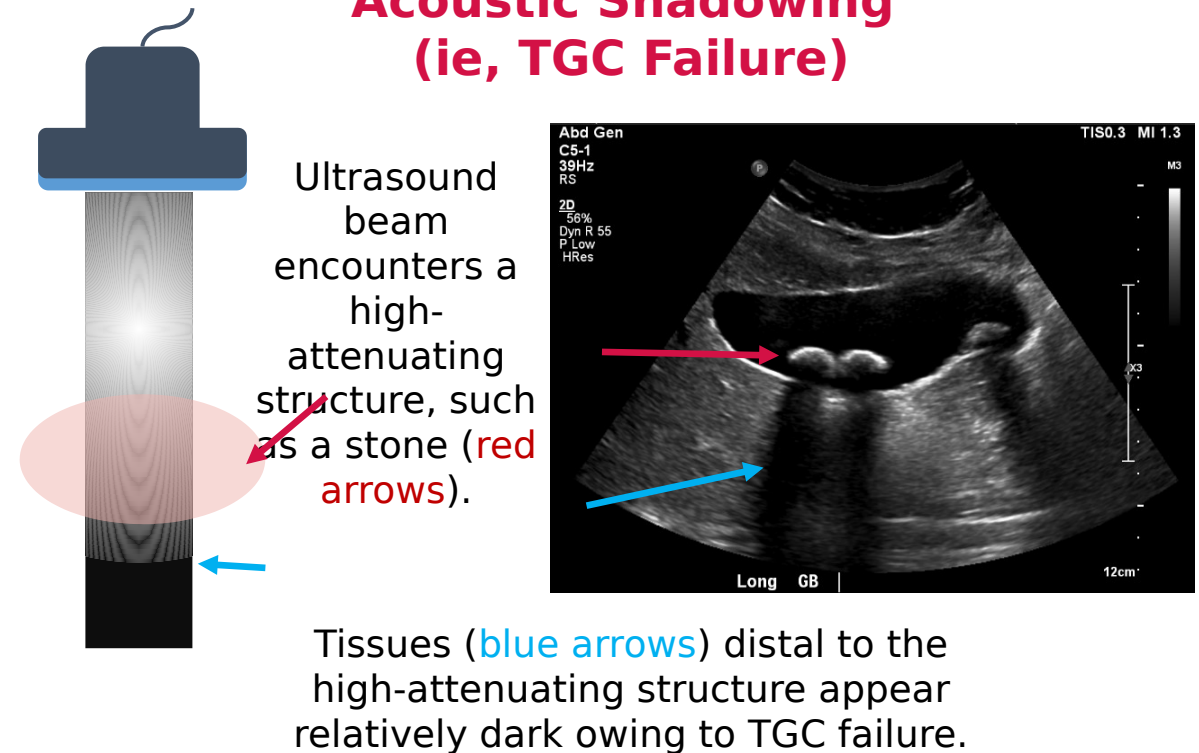
TGC and Attenuation Artifacts¹⁸

A baseline TGC setting assumes that attenuation is constant. However, if a portion of the tissue traversed is less or more attenuating, the resulting signals deep to those tissues will be over- or undercompensated, respectively. These artifacts are known as **increased through transmission (posterior acoustic enhancement)** and **acoustic shadowing**, respectively. TGC can be adjusted to decrease these artifacts and make an image appear more homogeneous. However, as these artifacts are generally useful for diagnosis, they are infrequently corrected.

Increased Through Transmission (ie, TGC Overcompensation)

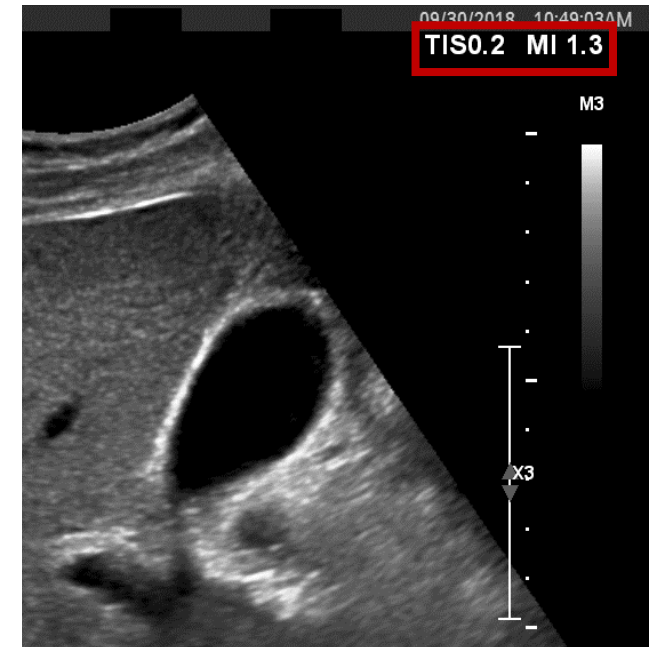


Acoustic Shadowing (ie, TGC Failure)



Power Output

- Most US transducers emit pulsed ultrasound beams, whereby brief bursts of acoustic energy are transmitted into the body. U.S. federal regulations limit the maximum voltage that can be supplied to create these pulses. Most US machines have a control setting to change power output.¹²
 - Increasing the power output increases the strength of the returning echoes. **The resulting image will be brighter.**
 - While US poses fewer known risks to patients than other imaging modalities, prudent use dictates the application of the “**as low as reasonably achievable,**” or **ALARA, principle** to minimize patient exposure to ultrasound energy.^{19,20}
 - An example of practicing the ALARA principle is to first increase the gain (rather than power output) if an image is too dark, or conversely to first reduce power output when an image is too bright.
- Key Points: Power output control changes the strength of the acoustic energy pulse transmitted to the body. Increased power output increases image brightness. Per the ALARA principle, the lowest possible power output should be used for the given diagnostic application.

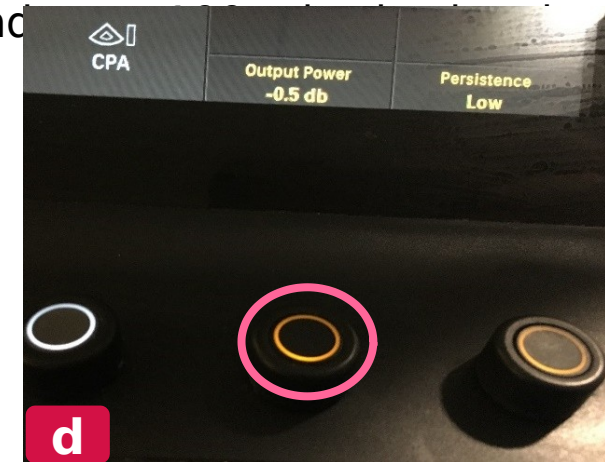
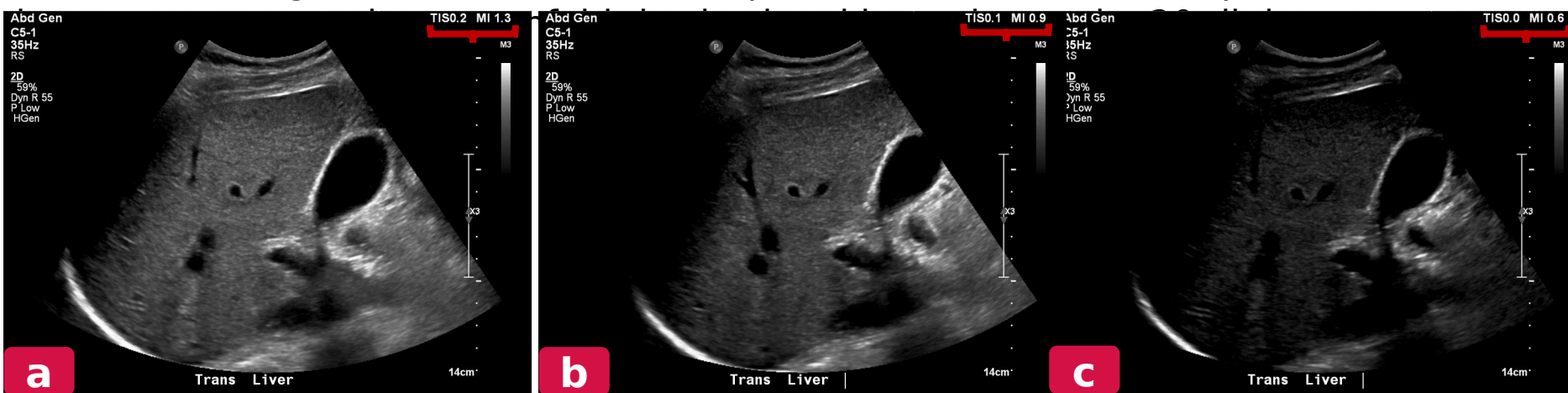


Adjusting power output affects the energy transmitted into the patient. This is reflected by the thermal and mechanical indices (rectangle) as depicted on the accompanying US image.

Modifying Power Output

Power output modifies the strength of the acoustic energy pulse transmitted into the body, which affects image brightness.

Changes in power output are displayed in decibels (db), a logarithmic scale that indicates the relative difference between two signal intensities. For example, a 3-db increase corresponds to a twofold rise in signal intensity, a 10-db



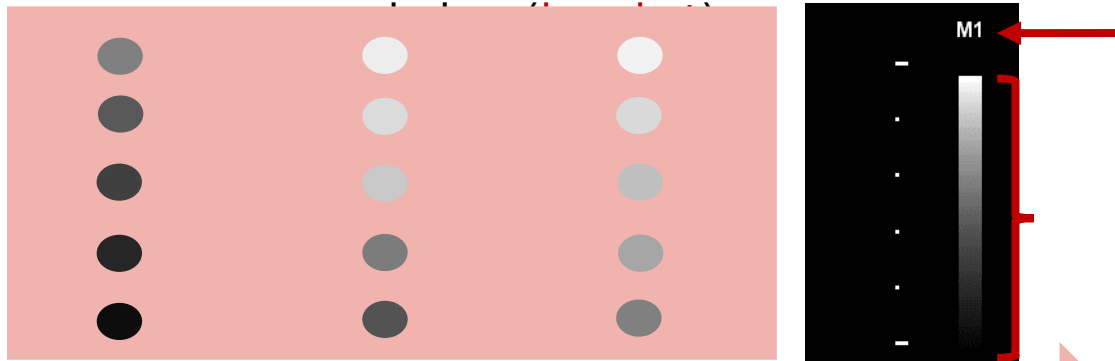
US images of the liver obtained with the power output set to the default strength (-0.5 db, **a**), decreased to -3 db (**b**), and decreased to -6 db (**c**). Using the logarithmic scale, -3 db is defined as one-half of the original output and -6 db is defined as one-fourth of the original output. Note that with decreasing power output, the image brightness decreases. This has a similar effect to that of adjusting the overall gain, but it also results in decreased energy transmitted to the patient, as noted on the screen display by the decreasing thermal and mechanical indices (brackets).

(**d**) Photograph shows the US console knob that is used to adjust output power (circle). Rotating the knob clockwise increases the power.

Key Points: Decreasing power output decreases image brightness. This has a similar effect to that of decreasing the overall gain but also results in decreased energy transmitted to the patient.

Gray Scale

This determines how light and dark each level will appear on the white-gray-black color display on the basis of the strength of the ultrasound signal.¹⁴ It is displayed as a notation (**arrow**) and



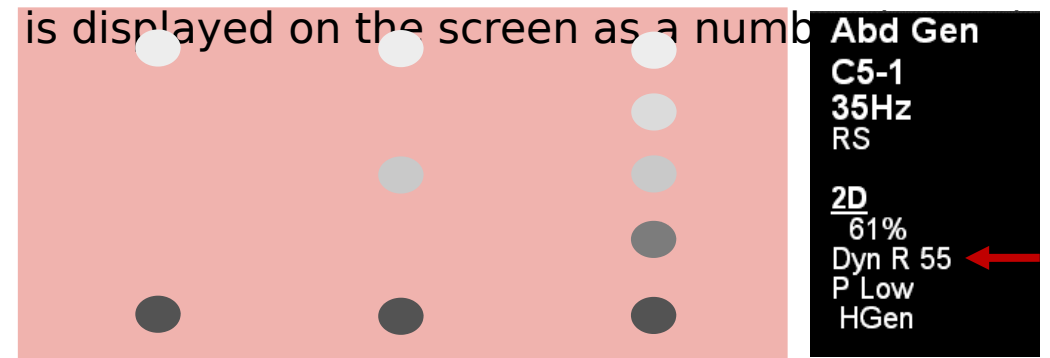
Increasing gray-scale map (M) intensity



US images show the effects of using progressively intense gray-scale maps, which increases from left to right (M5 → M3 → M1).

vs.

This setting adjusts the number of shades of gray between the smallest and largest signals.¹⁴ The lower range increases contrast. Using the wider ranges better detects subtle echogenic changes.¹² The dynamic range



Increasing Dynamic Range



US images show the effect of progressively increasing dynamic range, which increases from left to right (DR 30 → DR 55 → DR 70).

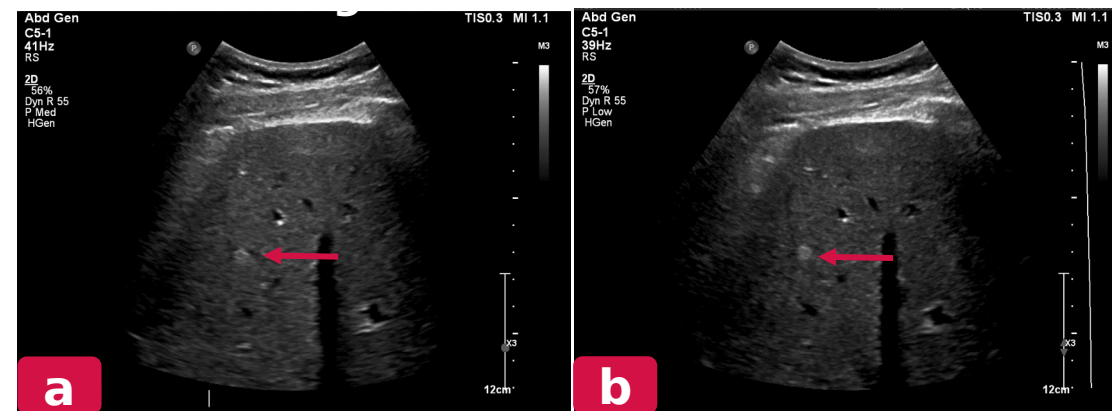
Spatial Compounding¹²

- **Speckle** is a major cause of poor image quality. Small tissue reflectors create a scattering effect and cause the characteristic graininess of US images. Increased speckle decreases contrast and the ability to discern subtle features.
- **Spatial compounding** reduces speckle and increases the contrast-to-noise ratio. Conventional US obtains an image from one angle, whereas spatial compounding sums images from multiple angles. True signals are reinforced, whereas speckle and other noise are not.
- The advantages include better identification of subtle conditions such as small cysts and calcifications.

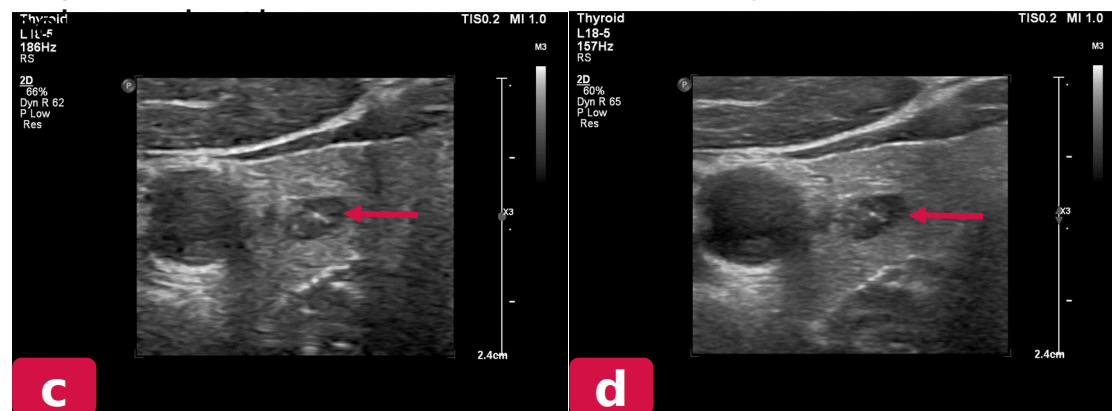
However, it can reduce artifacts, such as shadowing,

enhancement, comet-tail, or ring-down, which are key points. Spatial compounding improves image contrast-to-noise ratio by reducing speckle.

However, one must remember to turn off the setting when image interpretation requires the presence of shadowing, enhancement, comet-tail, or ring-down artifacts.



US images obtained with the spatial compounding setting **OFF** (a) and **ON** (b) show a liver hemangioma (arrow). Note that with this setting on (b), there is improved visualization of the hemangioma, with overall



US images obtained with the spatial compounding setting **OFF** (c) and **ON** (d) show a thyroid nodule (arrow). Note the improved visualization of the nodule in d, with overall noise reduction.

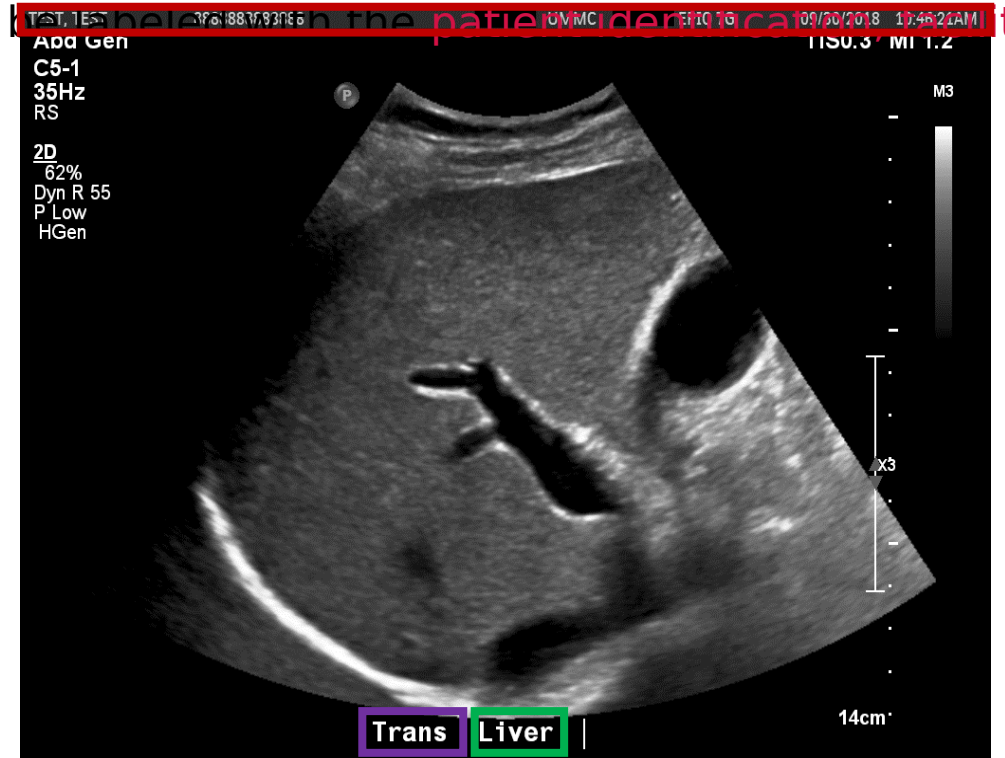
Annotations

The American College of Radiology, the Society for Pediatric Radiology, and the Society of Radiologists in Ultrasound (ACR-SPR-SRU) Practice Parameter for Performing and Interpreting Diagnostic Ultrasound Examinations, Section IV states:

“Adequate documentation is essential for high-quality patient care... Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should generally be accompanied by *measurements*. The *initials of the operator* should be accessible on the images or electronically on the [picture archiving and communication system] PACS. Images should be labeled with the patient identification.”¹⁹

Key Points

- Always label:
 - Patient and facility identification, examination date (**red rectangle**)
 - Image plane (**purple rectangle**)
 - Side
 - Organ (**green rectangle**), vessel, and measurements
- Check your institutional protocol for specific examination and additional requirements.
- Label placement matters! Do not cover the anatomy or the Doppler waveforms.⁸



Saving the Image

Key Points:

- Images can be saved in different formats, including still images (most common), cine loops, split-screen images, or extended FOV images.
- Specific steps for saving, reviewing, and exporting vary depending on the US machine manufacturer. Generally, only save the BEST images for interpretation. If multiple images of the same target are saved, the worst-quality

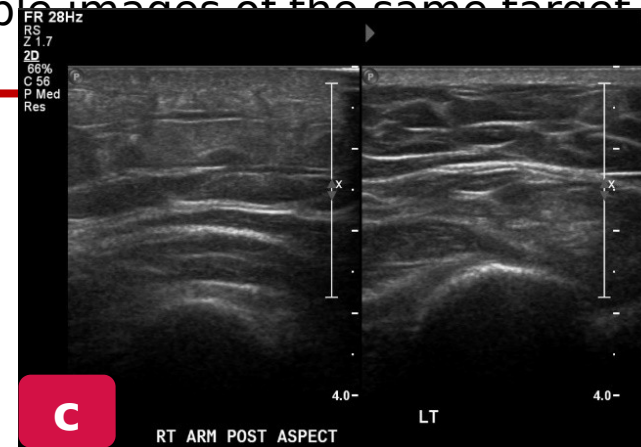
(a) STILL US IMAGE is the most commonly saved format. The “freeze” button holds the current image to allow for saving. The operator can also track back 3–4 seconds and choose the best frame to save.²¹



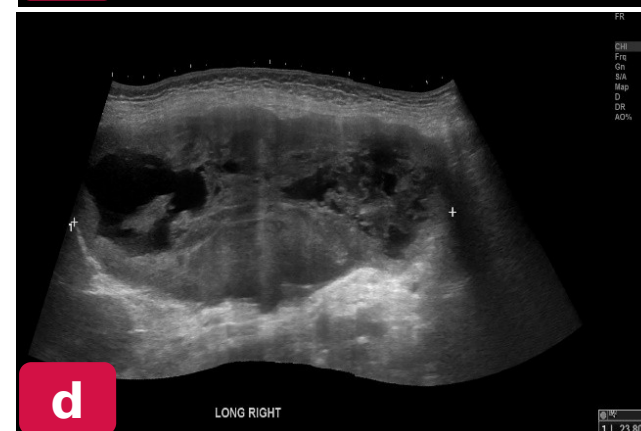
(b) CINE LOOP saves a sequence of images that can be viewed as a 2–60-second video loop.¹⁵ This can supplement still US images and allow the radiologist to view an entire organ or area.



Click the
accompanying US



(c) SPLIT SCREEN is a useful tool for direct comparisons (eg, the left vs right side). In this accompanying split-screen US image of the upper extremity soft tissues, superficial edema on the right is more apparent when compared to that on the normal left side.



(d) EXTENDED FOV is a saving option in which images across the anatomic region of interest are accumulated to create one large panoramic image.²² In this example, a 23-cm intra-abdominal gastrointestinal stromal tumor is able to be captured in one composite

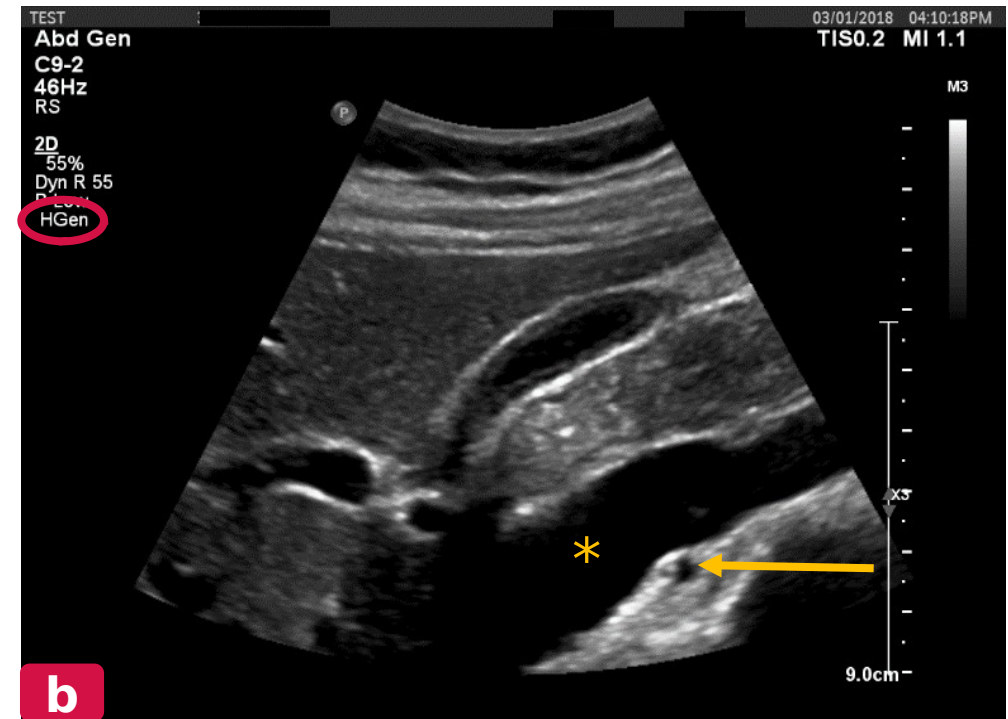
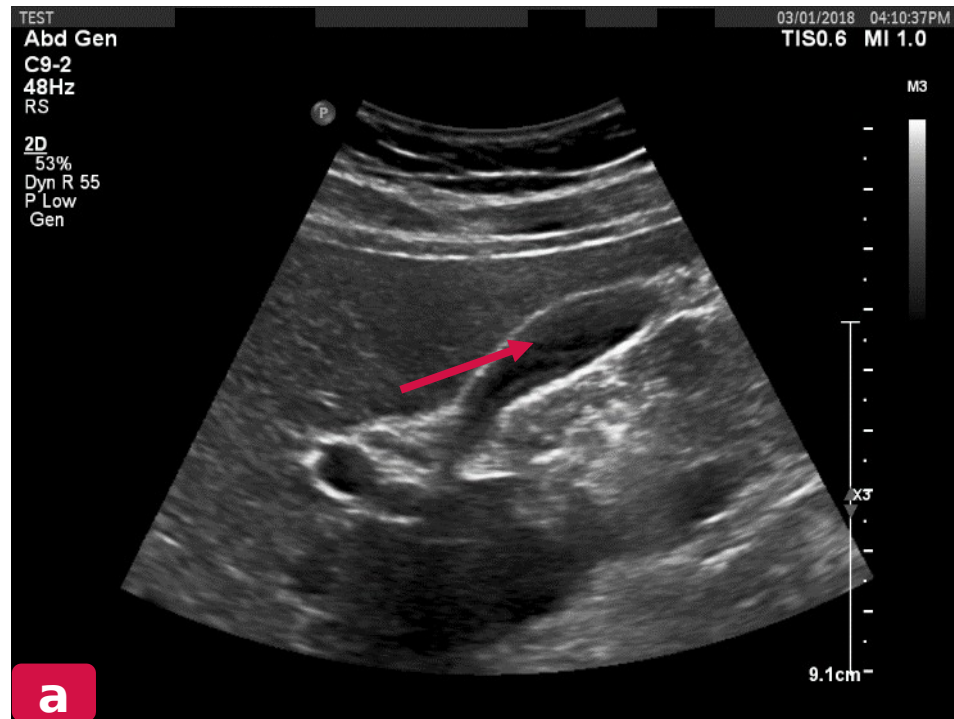
Cases: Troubleshooting

Case 1, Question A: You are performing a US examination of the gallbladder in a patient with intermittent right upper quadrant abdominal pain, nausea, and vomiting. As you are scanning, you notice some echogenicity within the gallbladder lumen and are unsure whether that is an artifact or a true ultrasound signal. What setting should you check first?

- A) Gain
- B) Harmonics
- C) Power output
- D) Frequency



Cases: Troubleshooting



ANSWER: B, HARMONICS

The tissue harmonics setting reduces side lobe and reverberation artifacts (**a**, **arrow**) when imaging cystic structures. In image **b**, note the screen display indicates that the harmonics has been turned on (**circle**). Also, note the reduced artifact and improved visualization of the inferior vena cava (*) and right renal artery (arrow in **b**). Adjusting the gain is unnecessary, as the image brightness is not a problem. Similarly, changing the power output alters the overall brightness of the image and would not clear the present artifact. Adjusting the frequency could be considered, but it appears to be adequate given the type of transducer used for the examination (C9-2).

Cases: Troubleshooting

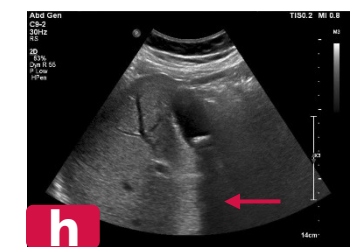
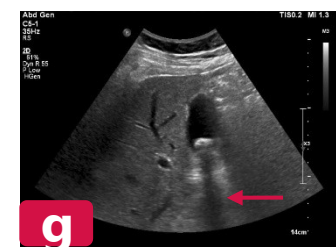
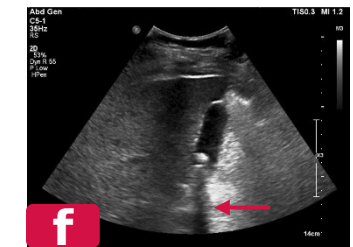
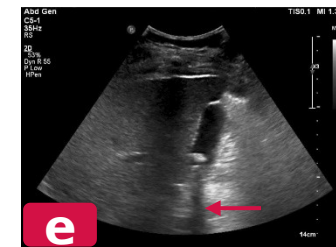
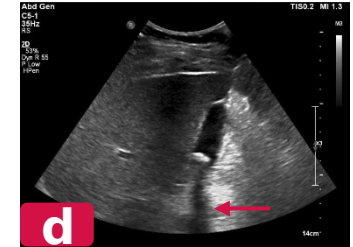
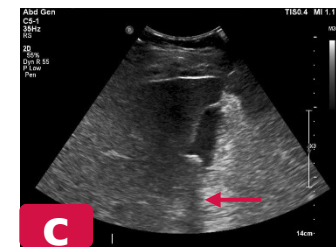
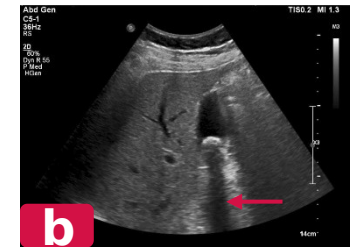
Case 1, Question B: For the same patient seen in Case #1A, you suspect the presence of a gallstone and therefore will look for acoustic shadowing. Name four settings to adjust or review that can enhance visualization of this diagnostic artifact.

1) **TURN OFF SPATIAL COMPOUNDING.** Recall that spatial compounding reduces speckle but may also reduce useful artifacts such as shadowing.¹⁸ Images **a** and **b** show the effect on acoustic shadowing with spatial compounding ON and OFF, respectively.

2) **TURN ON THI.** Recall that THI is useful for enhancing some diagnostic artifacts, such as shadowing. Images **c** and **d** show the effect on acoustic shadowing with THI OFF and ON, respectively.

3) **ENSURE FOCAL ZONE PLACEMENT IS AT THE LEVEL OF THE TARGET OF INTEREST.** Inappropriate focal zone placement can decrease shadowing. Adjust the focal zone, or consider adding multiple focal zones.¹⁸ Images **e** and **f** show the effect on acoustic shadowing with inappropriate and appropriate focal zone placement, respectively.

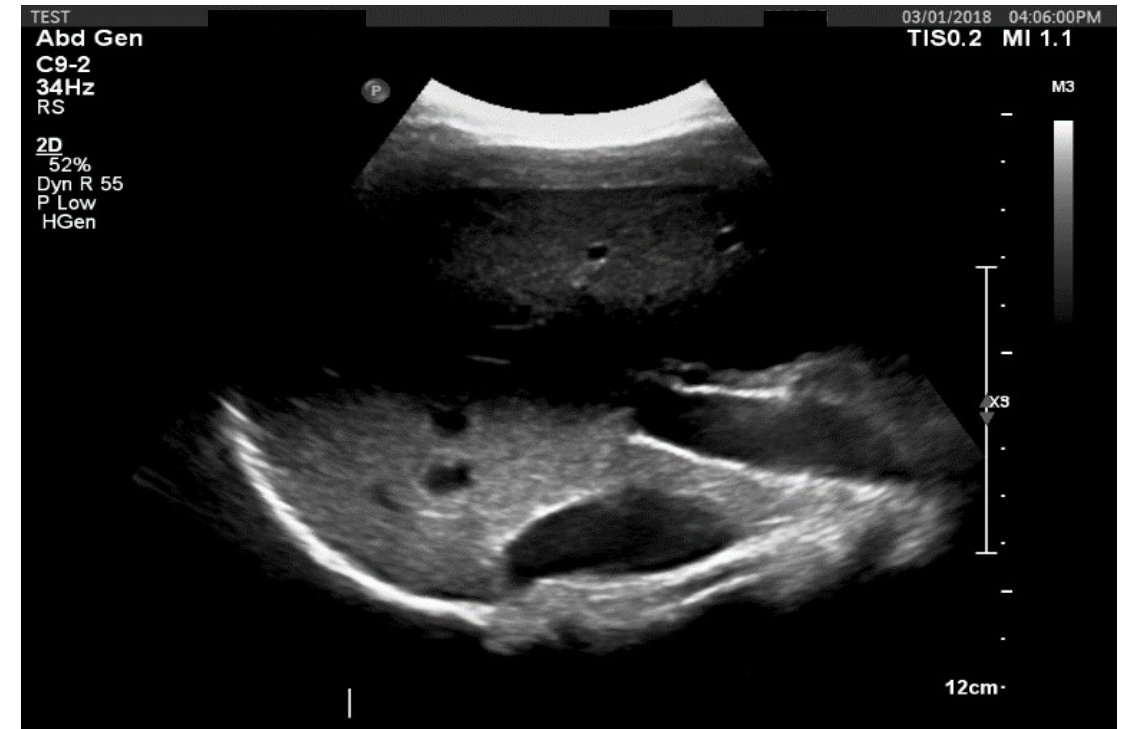
4) **ADJUST THE FREQUENCY:** Increasing the frequency will enhance shadowing. Images **g** and **h** show the effect on acoustic shadowing when low- and high- frequency transducers are used, respectively.



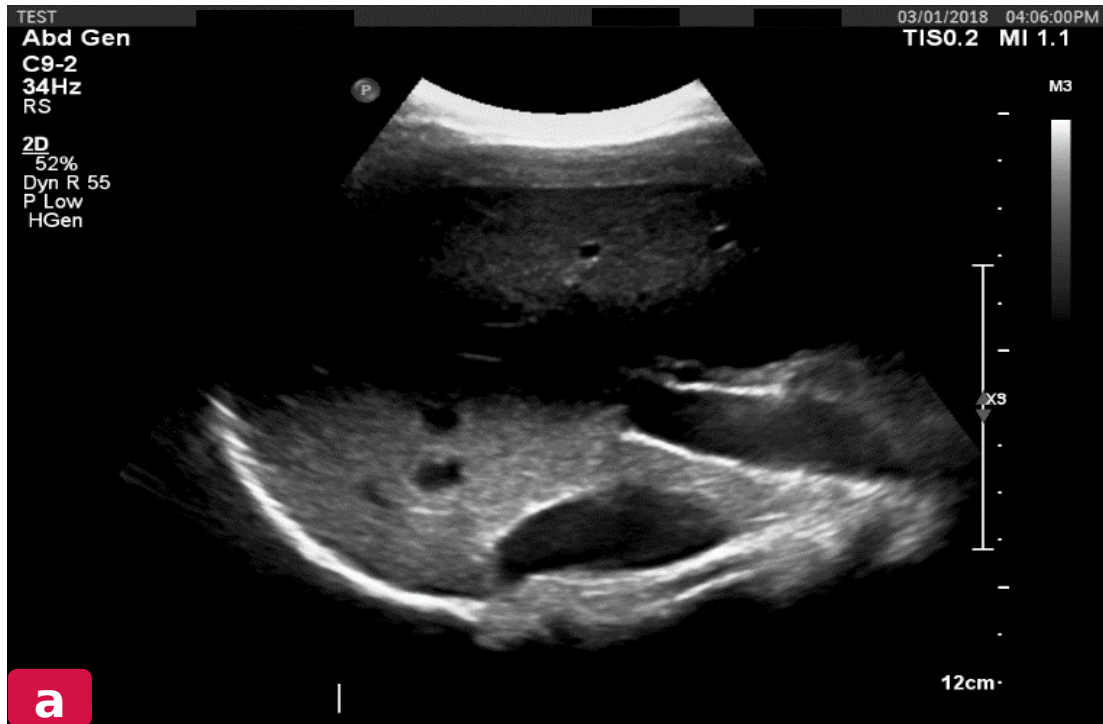
Cases: Troubleshooting

Case 2: You are scanning a patient's liver and see this image on the US machine display. What setting should you adjust first to improve the image quality?

- A) Harmonics
- B) Dynamic range
- C) Depth
- D) TGC



Cases: Troubleshooting



**ANSWER: D,
TGC**

TGC enables equally reflective structures to display uniform brightness, regardless of depth (note the uniformity of **b**). In image **a**, the middle depth is inappropriately dark. The superficial-middle TGC slide pods on the US machine console should be adjusted to the right to increase the brightness at these depths. The harmonics setting does not need to be adjusted, as it is turned on. The dynamic range setting can affect contrast, but appropriate levels of contrast are depicted at the deeper levels, suggesting an appropriate dynamic range (which is set to 55). The depth is appropriately set at 12 cm, as the full span of the liver is centered on the screen, and adjusting this would not change the brightness of the image.

Cases: Troubleshooting

Case 3: What is the focal zone for this US image of the pancreas?



The focal zone is set to a depth of 3-9 cm.

Conclusion

- US image optimization is a learned and practiced skill.
- The basic steps for performing a successful gray-scale US examination include:
 - ✓ Proper patient, operator, and equipment set-up
 - ✓ Appropriate transducer selection
 - ✓ Understanding the information on the screen display
 - ✓ Understanding the US machine console settings and how to manipulate them to optimize imaging
 - ✓ Saving the image
- Transducers vary in shape, size, and frequency. Selecting the right transducer for the right application is critical.
- Understanding the screen display and image notations improves image interpretation, especially when interpreting images acquired by a colleague.
- Mastering US scanning techniques improves recognition of suboptimal images and enables the radiologist to use or suggest techniques to improve image quality.



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Suggested Readings

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